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# Estimated Deficiencies Resulting from Reduced Protein Content of Staple Foods: Taking the Cream out of the Crop?

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Projected changes in climate are expected to play a complicated role in global crop production. Rising levels of atmospheric carbon dioxide ($CO_2$) may improve yield, but higher average temperatures and more frequent extreme weather could damage crops, increase the risk of foodborne illness, and impair distribution of safe and nutritious food.[1] However, there is another, less intuitive potential effect on the global food supply and human nutrition that also warrants consideration: reductions in the nutrient content of food staples eaten around the world.[2] A new study in *Environmental Health Perspectives* presents an early estimate of impacts due to changes in one of these nutrients, protein.[3]

As levels of atmospheric $CO_2$ rise, concentrations of protein[4,5] and essential minerals such as calcium, magnesium, zinc, and iron[4,6,7,8] decline in most vascular plants, particularly those plants that utilize what is known as $C_3$ photosynthesis. $C_3$ plants respond to increased concentrations of atmospheric $CO_2$ more vigorously than $C_4$ plants. $C_3$ plants represent most of the Earth's plant cover[9] and include staples such as rice, wheat, barley, and potatoes.[10]

Consequences for public health are difficult to predict and depend on a range of variables, including local diet and farming practices. "The two effects [increased production and decreased nutrient content] come as a set, so there will be those who benefit and those who are harmed by these changes, depending on many factors," says Justin McGrath, a postdoctoral research associate at the University of Illinois Urbana-Champaign, who was not involved in the current study.

By analyzing regional diets worldwide and modeling likely changes to protein content triggered by elevated levels of $CO_2$, the authors of the new study estimate that by the year 2050 more than 148 million people could become newly at risk for protein deficiency.[3] "What this work shows, as well as a lot of other research, is that anthropogenic disruptions of most of Earth's natural systems have significant impacts on global health," says senior author Samuel Myers of Harvard University. Myers is working to synthesize existing research on $CO_2$ and human nutrition in hopes of raising awareness of this potential problem among researchers and the public.

Protein intake and socioeconomic status are closely linked, says lead author and former Harvard research fellow Danielle Medek, and current disparities are likely to be exacerbated by climate change. "The people with the most impoverished diets within a country are most likely to lack animal sources of protein and therefore likely to be disproportionately affected [by reduced intake of protein from plants]," she says. Medek and colleagues estimate, based on data from the Food and Agriculture Organization of the United Nations,[11] that 82% of the world's population currently derives most of its daily protein from plants.[11]

The stimulated carbohydrate production and plant growth induced by higher levels of atmospheric $CO_2$ can itself lead to comparatively lower nutrient concentrations in plants, McGrath explains. Although researchers do not fully understand all the mechanisms involved, one contributor to this imbalance appears to be simple dilution. "You have got more carbohydrates, which dilute everything else," he says. In addition, he says, "There is evidence that affected plants may take up less of some, but not all, nutrients from the soil."[6]

However, the increase in carbohydrate concentration may be the main driver of health effects associated with the phenomenon, says Irakli Loladze, a professor at Bryan College of Health Sciences. "It is like sprinkling every portion of plant-based foods

In many poorer, rapidly populating countries, people rely on so-called $C_3$ plants such as wheat and rice for protein. Millions of people could be at risk of protein deficiency—including 92 million in India alone—as rising atmospheric $CO_2$ levels reduce the protein content in these plants. Image © Zvonimir Atletic/Shutterstock.

with sugar," he says. Loladze, who was one of the first to call attention to the link between $CO_2$ and the quality of human nutrition,[8] was not involved in the current study.

In order to estimate risk, the researchers compared projected daily intake of protein against the U.S. Institute of Medicine's nutrient reference values.[12] But as Medek points out, health effects may also occur among those whose projected protein intake falls just shy of the threshold, and among the 1.4 billion people around the world thought to already be at risk of protein deficiency.

Daniel Taub, a professor of biology at Southwestern University, says he is wary of the idea of predicting declines in plant protein attributable to rising atmospheric $CO_2$. "The extent to which carbon dioxide affects protein concentration depends on a lot of different things," he says, many of which are unpredictable and subject to human modification, such as nitrogen levels in the soil and specific cultivars planted. "The real-world effect under real agricultural conditions will always be variable and impossible to predict with precision and accuracy," he says.

He does not, however, dispute the study's core finding that impacts will be concentrated in poorer, rapidly populating regions where people rely on $C_3$ plants for protein. India alone—with its high consumption of rice and wheat coupled with its large and rapidly increasing population[13]—accounts for more than one-third of the individuals predicted by the study to be put newly at risk of protein deficiency.[3]

"In a qualitative way, what the authors are saying is that India is a place to look out for. Absolutely, no question, they are among the people I would look out for," Taub says. But he adds that people in Bangladesh, Vietnam, Cambodia, and central Asian countries such as Azerbaijan and Tajikistan derive an even higher percentage of their calories from $C_3$ grains. "All of these countries," he says, "may face real challenges with this in the future."

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